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INTEGRAL INDICATOR OF INDUSTRIAL SAFETY OF HAZARDOUS PRODUCTION FACILITIES OF FERROUS AND NON-FERROUS METALS PROCESSING IN THE ROSTOV REGION

Zhokhov R.V., Korotkiy A. A.
Don State Technical University, Rostov-on-Don, Russian Federation

RomikZ@bk.ru
korot@novoch.ru

The article considers application of an integral indicator of industrial safety in relation to hazardous production facilities (HPF) of ferrous and nonferrous metals processing in the Rostov region. The integral indicator is determined on the basis of individual indicators used to assess the probability of potential negative consequences of non-compliance with the requirements in the field of industrial safety.

Keywords: hazardous production facility, foundry, metal, industrial safety

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ИНТЕГРАЛЬНЫЙ ПОКАЗАТЕЛЬ ПРОМЫШЛЕННОЙ БЕЗОПАСНОСТИ ОПО ПЕРЕРАБОТКИ ЧЕРНЫХ И ЦВЕТНЫХ МЕТАЛЛОВ В РОСТОВСКОЙ ОБЛАСТИ

Жохов Р. В., Короткий А. А.
Донской государственный, технический университет, Ростов-на-Дону, Российская Федерация
RomikZ@bk.ru
korot@novoch.ru

Рассматривается применение интегрального показателя промышленной безопасности применительно к опасным производственным объектам (ОПО) переработки черных и цветных металлов в Ростовской области. Интегральный показатель определяется на основе отдельных показателей, используемых для оценки вероятности возникновения потенциальных негативных последствий несоблюдения требований в области промышленной безопасности.

Ключевые слова: Опасный производственный объект, литейный цех, металл, промышленная безопасность.

Introduction. Foundry in mass production is an integral part of the technological process and belongs to the category of processing of ferrous and non-ferrous metals. Maintaining a high level of industrial safety can prevent or minimize the consequences of an accident. An integral indicator allows assessing the probability of potential negative consequences of non-compliance with industrial safety requirements. It is formed from factors that are evaluated in points by selecting values on a linguistic (nominal) scale. The degree of influence of individual factors on the level of industrial safety is taken into account by means of weight coefficients.

Determination of external factors. All external factors can be divided into three groups:

1. Man-made factors, including the presence of hazardous facilities or the movement of hazardous substances in the area of HPF. In foundries, these factors are necessary for the production process.
2. Anthropogenic factors that depend directly on the location of HPF in the region relative to human settlements. Most foundries in the Rostov region are located within the city limits, but are localized in industrial districts. The location of residential buildings, places of mass events and transport passenger facilities is within acceptable limits, but it affects the overall indicator of industrial safety negatively.
3. Natural factors (wind load, the possibility of earthquakes, fire danger, the possibility of volcanic eruptions) that depend directly on the region and for the Rostov region are optimal.

General characteristics of the enterprise. On the territory of the Rostov region, legal entities are the main owners of industrial production, which includes foundries. The presence of a compulsory insurance contract and a license in the field of industrial safety is strictly controlled for such enterprises. Compliance with all the requirements necessary for them significantly reduces the probability of potential negative consequences. The area of the territory and location of the foundry facilities must comply with both the technological process and industrial safety standards.

Technical and technological characteristics of HPF. The characteristic of HPF is formed depending on the following parameters:

1. The age of the object and the deprecation of both production assets and buildings and structures. Foundry production in the Rostov region started in the 1920s and has been modernized to the present day. The wear parameter is determined by the arithmetic mean of the years of commissioning, which corresponds averagely to the 1980-th year.

2. Quantitative characteristics of explosive, combustible and toxic substances, technical devices both tested and modernized.

3. Availability of technical solutions aimed at prevention of accidents and prevention of depressurization of equipment and pipelines. The presence of automatic control system, locks, alarms and other safety means. Hazardous production facilities of the Rostov region are equipped with all the above mentioned solutions and systems.

Staff. The level of training and competence of the staff is directly related to HPF safety. One of the main causes of emergencies is the human factor. The following conditions allow minimizing the influence of the human factor:

• sufficient number of certified industrial safety personnel for the last 5 years;

• a system for the training of personnel in case of emergency, the presence of special stands, training sessions and drills that significantly improve staff preparedness;

• compliance with the procedure for admission of personnel to independent work;

• availability of a system of professional training (advanced training) of personnel;

• provision of personal protective equipment for personnel;

• availability of local emergency alarm system.

Enterprise of the Rostov region observe these conditions, which is supported by the relevant materials in the reports of Rostekhnadzor.

Units. All HPF of the Rostov region with foundries include medical service, fire protection facilities, emergency rescue teams and organize non-professional emergency teams of the employees. Training sessions and training alarms allow them to control the degree of preparedness of these formations.

Organization of production supervision. Production supervision is an integral part of industrial safety. The main conditions of its implementation:

• availability of a plan of measures to ensure industrial safety;

• at least one inspection per year with corrective actions;

• availability of proposals to improve the quality of industrial safety;

• appointment of responsible employees and systematization of information on the organization and implementation of production supervision.

All these points are executed according to the regulations on production supervision on observance of requirements of industrial safety on dangerous production facilities developed individually for each HPF (foundry shop) according to the following documents:

1. Federal law no. 116-FZ of 21.07.1997 "On industrial safety of hazardous production facilities".

2. "Rules of organization and implementation of production supervision over compliance with the requirements of industrial safety at a hazardous production facility". Approved by the decree of the Gov-

ernment of the Russian Federation of 10.03.1999, no. 263, amended by resolutions of the Government of the Russian Federation of 01.02.2005 no. 49, of 21.06.2013 no. 526, 30.07.2014, no. 726).

3. "Procedure for technical investigation of the causes of accidents, incidents and cases of loss of industrial explosives at the facilities supervised by the Federal Service for Environmental, Technological and Atomic Supervision". Approved by order of Rostekhnadzor of 19.08.2011 no. 480, amended by order of Rostekhnadzor of 25.12.2014 no. 609.

Rostekhnadzor inspections. Rostekhnadzor inspections are conducted in accordance with the plan of scheduled inspections by the Federal Service for Environmental, Technological and Nuclear Supervision. The identified violations are eliminated, and the requirements are fulfilled in time and in full, which is confirmed by the lack of suspension of the activities of the HPF.

Industrial safety expert review. Expert reviews are carried out in accordance with article 13 of Federal law "On industrial safety of hazardous production facilities" of 21.07.1997 no 116-FZ amended on 29.07.2018. Information from the Register of expert opinions on industrial safety are freely available on the website of the Federal Service for Environmental, Technological and Nuclear Supervision http://sevkav.gosnadzor.ru.

Material and financial resources. Availability of material and financial resources for localization and elimination of consequences of accidents is confirmed by the corresponding orders issued at the enterprises of the Rostov region, which include HPF (foundries).

Fire hazard of the facility. The presence of hand fire extinguishing means and automatic fire alarm systems are mandatory. They are formed according to the specifics and equipment of the foundry.

Prevention of outside interference. For HPF, the availability of technical means of protection and unarmed security is a prerequisite for reducing the impact of the human factor on technological processes, a condition for limiting access and the terrorist threat.

Accidents and injuries. According to the annual reports on the activities of the Federal Service for Environmental, Technological and Nuclear Supervision at metallurgical and coke and by-product process facilities, which include HPF (foundries), the Rostov region is not included in the distribution statistics of accidents and emergencies [1].

Calculation of accident risk. The calculation is carried out individually for a HPF (foundry) on the following parameters:

• value of tangible risk;
• material damage for the maximum possible accident;
• humanitarian risk indicator;
• frequency of occurrence of the maximum possible accident;
• number of deaths and injuries among workers and other persons for the maximum possible accident.

Conclusion. The result of the application of the technique is to obtain a risk-oriented integrated indicator of industrial safety, which characterizes the level of accident risk on the HPF, equal to an average of 2.69 on a 3-point scale [2].

The results show that the state of industrial safety of hazardous production facilities (foundries) of the Rostov region can be generally characterized as "excellent". Nevertheless, it is worth paying attention to the prevention of violations of the technological process and increasing the level of production supervision, the main causes of accidents and emergencies in other regions of the Russian Federation.

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Autors:

Zhokhov Roman Valerevich,
postgraduate student "Operation of transport systems and logistics", Don State Technical University, (1, Gagarin sq., Rostov-on-Don, 344000, Russia),
RomikZ@bk.ru

Korotkiy Anatoliy Arkadyevich,
head of the Department "Operation of transport systems and logistics", Don State Technical University, (1, Gagarin sq., Rostov-on-Don, 344000, Russia), doctor of techn. sciences,
korot@novoch.ru

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ASSESSMENT AND MONITORING OF DANGEROUS FACTORS IN THE AREA OF STEEL ROPES SPLICING

Korotkiy A. A., Marchenko E. V.
Don State Technical University, Rostov-on-Don, Russian Federation

daedwardrambler.ru@mail.ru
korot@novoch.ru

In the article, the authors conduct research on the assessment and control of hazards in the area of steel ropes splicing. The obtained results made it possible to clarify the reasons for the formation of dangerous factors such as: "undulation", wire strands breaks and loss of diameter of the steel rope. The main reason for the occurrence of dangerous factors is the uneven loading of wires and strands in the cross section of the steel rope. With the existing manual method of jointing, it is technologically impossible to ensure the uniformity of loading of all tucked strands, due to errors occurring on the length of each tucked strand, which directly depends on the human factor (experience and professionalism of the splicer) in the course of work. The authors propose a new method of jointing steel ropes using a polymer core, which is a conductor, which allows to exclude the human factor and to keep in place of jointing the permissible values of defective indicators by diameter.

Keywords: steel rope, machines operation, cable traction, splicing, acceptance indicators, hazards factors, polymer materials.

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ОЦЕНКА И КОНТРОЛЬ ОПАСНЫХ ФАКТОРОВ В ЗОНЕ СЧАЛКИ СТАЛЬНЫХ КАНАТОВ

Короткий А. А., Марченко Э. В.
Донской государственный технический университет, г. Ростов-на-Дону, Российская Федерация
daedwardrambler.ru@mail.ru
korot@novoch.ru

Проведены исследования оценки и контроля опасных факторов в зоне счалки стальных канатов. Полученные результаты позволили уточнить причины образования опасных факторов, таких как «волнистость», обрывы проволок прядей и потери диаметра стального каната. Основной причиной возникновения опасных факторов является неравномерность нагружения проволок и прядей в поперечном сечении каната. При существующем ручном способе счаливания технологически невозможно обеспечить равномерность нагружения всех заправляемых прядей в связи с погрешностями, возникающими в ходе проведения работ на длине каждой пряди. А это напрямую зависит от человеческого фактора (опыта и профессионализма счальщика). Авторами предложен новый способ счаливания стальных канатов с применением полимерного сердечника, являющегося кондуктором. Сердечник позволяет исключить человеческий фактор и сохранить в месте счаливания допустимые значения браковочных показателей по диаметру каната.

Ключевые слова: стальной канат, эксплуатация машин, канатная тяга, счалка, браковочные показатели, опасные факторы, полимерные материалы.

Introduction. In modern engineering, we use the machines with cable traction for high-tech tasks. Its characteristic is the use of steel ropes of an endless (infinite) type, where the rope is a ring with the formation of a section of its connection (jointing), called splicing. Splicing may be used as a method of joining two ends of a rope by weaving the strands of the outer layer to the core with the length sufficient

for the formation of structural latches (nodes) of the tucked strands. The process of steel ropes splicing is realized manually by a certified splicer and is regulated by normative documents [1, 2].

Problem statement. In the study of the durability of steel ropes, despite the declared by the manufacturer resource of 15-20 years, the authors noted that after 5-6 years there are dangerous factors in the places of jointing: breaks, wear of wires, reduced diameter of the rope as a result of some damage to the core, loss of internal section, "undulation". All this is the basis for unscheduled repair of the rope with the replacement of the defective section and leads to significant material costs. These factors indicate a violation of physical and mechanical characteristics of the steel rope in the splicing area and lead to its premature wear [3, 4].

Theoretical part. Physical modeling of steel ropes splicing process allowed the authors to establish the causes of hazards in the area of splicing. For normal operation of the steel rope, it is necessary that the resultant load is equally applied to all wires and strands in their cross section [5]. However, in the splicing area there is a displacement of the resultant load relative to the axis by the amount of eccentricity, consequently, there is an uneven loading of wires and strands of the rope. Uneven loading appears in splicing nodes, as in manual splicing it is impossible to ensure the constancy of the length of each of the loaded strands. Excessive torque moment appears when operating with the load displacement equal in effect in cross section of the rope splicing along its length. The tucked strands are in a rigidly fixed state and do not provide the required mobility when bending the rope on the pulley (wheel). In the joint "lock" of the friction pair "core — strand — strand", the effect of "biting" of tucked strands appears, which in the process of operation leads to the formation of a dangerous factor called "undulation" (Fig. 1) [6].

Fig. 1. Formation of dangerous "undulation" factor in the area of steel rope splicing

The displacement of the resultant load in the cross-section of the steel rope significantly reduces the level of safety during its operation. When the "undulation" develops, the loading in the cross section of the wire when the rope is bent on the pulley increases due to additional bending and tensile stresses. These stresses exceed the calculated values; because of that, most loaded wires of the strand begin to collapse at a lower number of loading cycles, which in turn leads to the formation of such a dangerous factor as the wire breakage (Fig. 2) [7].

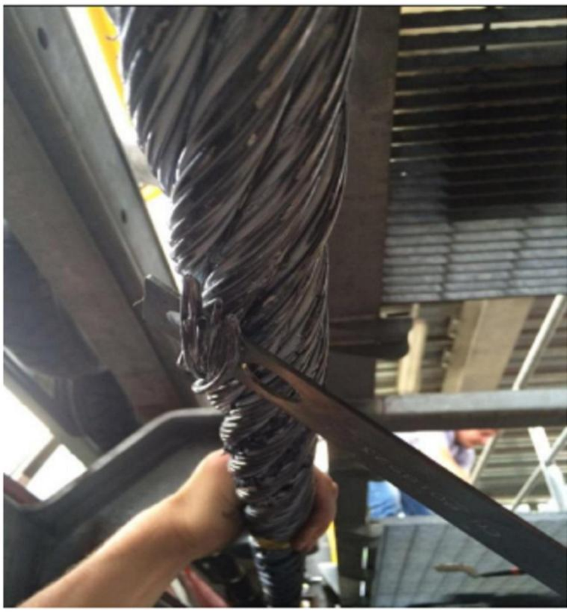
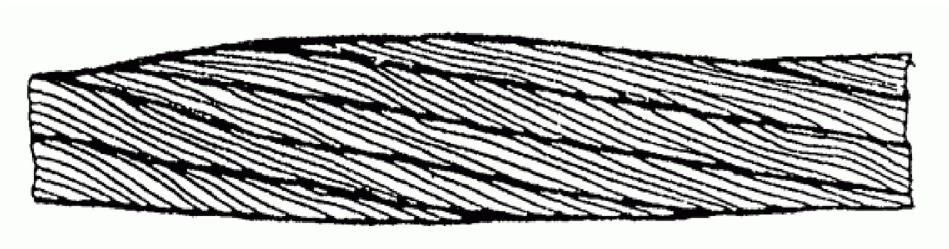
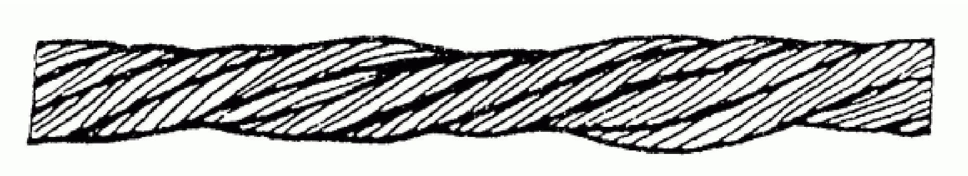


Fig. 2. Breakage of wires of one of the strands in the splicing area of the steel rope

With the existing manual method of splicing, it is technologically impossible to ensure the uniformity of loading of all tucked strands due to the arising errors on the length of each tucked strand, which directly depends on the human factor (experience and professionalism of the splicer) during the work [8]. The impossibility of ensuring the accuracy of cutting the tucked strand to the required length causes undesirable consequences. Cutting off a strand with an excess length when it is placed, leads to an increase in the diameter of the rope. If the strand is cut too short, there is the lack of support for the outer strands. The lack of support can reach several millimeters, which leads to a localized reduction in the diameter of the rope. More or less hard contact between the adjacent outer turns may result in the early emergence of various wire damages in this area. An increase or decrease in the diameter of the steel rope by more than 10 % of its nominal value is also a dangerous factor (Fig. 3) [9].



a)



b)

Fig. 3 Hazardous factor in the form of local increase (a) or decrease (b) of the steel rope diameter in the splicing area

Scientific novelty. The conducted researches allowed us to form a method of assessment and control of dangerous factors in the splicing area, as well as to improve the method of steel ropes splicing. The basis of the improved method is the polymer core developed by the authors, which can serve as a conductor that allows you to keep the permissible values of rejection indicators on diameter in the splicing area.

The splicing conductor is a hollow polymer cylinder with a length exceeding the length of the splicing to the value of the two extreme ends of the tucked strands. The outer profile of the conductor in the cross section is made in the form of a star with the number of rays equal to the number of strands and the height of the rays is not less than half the diameter of the strand. The conductor has a helical shape with a rope turns equal to the strand pitches in the rope, and with a radius of segments between the rays equal to the radius of the cross section of the strand. In this case, the rays at the top are made in the form of a dovetail, and the hollow cylinder in each joint unit of the "joint" has oval holes corresponding to the diameter of the cross section of the strand in the shrink tube at an angle of the lay. The number of holes is equal to twice the number of strands. The holes are evenly staggered along the helical line along the conductor, in pairs by the number of strands and strictly opposite each other by the radius of the hollow cylinder (Fig. 4).

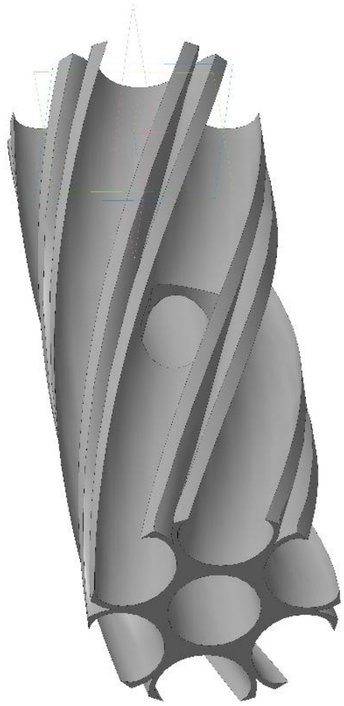


Fig. 4. Polymer conductor for steel ropes splicing

To ensure mobility of the strands in a joint (node) of a rope, the ends are clamped by a shrink tube with the subsequent temperature processing. Before that, the powder antifriction material is placed inside the tube. This material due to its layered structure provides mobility of the splicing strands by sliding powder nanoparticles, which has good adhesion properties in the friction system "core — strand — strand", where there is the displacement of the layers of this material. This eliminates the possibility of the effect of "biting" of the splicing strands in the splicing joint. To ensure the mobility of the strands in the body of the conductor, a powder antifriction material is sprayed on its surface, filling the surface of the conductor and the inter-strand cavities. This allows the strands of the outer layer to move in the longitudinal plane and around their axis, dividing the resultant load throughout the rope and minimizing wear from the conductor at the bending of the rope on the pulley (wheel).

The existing core on the entire splicing length is replaced by the conductor design, consisting of a movable cylindrical rod, the diameter of which is equal to the diameter of the strands in the shrink tube, which allows ensuring the completeness of the support area of the strands of the outer layer and eliminates the formation of voids due to the lack of length of the splicing strands. The ends of the strands in the heat-shrink tube are spliced into the body of the hollow cylinder of the replaced core, passing them through the oval holes in each "joint" by replacing the movable cylindrical rod with the ends of the

strands treated with a heat-shrink tube. Then they put a solid line on the outer surface of the rope along the length of splicing and under the load control its straightness (Fig. 5).

Fig. 5. Control line of axial displacement (torsion) of steel rope around its axis

Conclusion. The conducted by the authors researches allowed them to clarify the reasons for the formation of dangerous factors in the areas of steel ropes splicing. Timely identification and elimination of hazards let us keep to a minimum damage to people and property at the enterprises that operate machines with a traction rope. The main advantage of the improved steel rope splicing is the exclusion of the human factor during splicing. The conductor proposed by the authors can be manufactured for any type of a steel rope according to the specified parameters with the pre-prepared oval holes for strands splicing of the outer layer into the joint, which significantly improves the splicing quality.

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Autors:

Korotkiy Anatoliy Arkadyevich,
head of the Department "Operation of transport systems and logistics", Don State Technical University, (1, Gagarin sq., Rostov-on-Don, 344000, Russia), doctor of techn. sciences,
korot@novoch.ru

Marchenko Edvard Viktorovich,
assistant of the Department "Operation of transport systems and logistics", Don State Technical University, (1, Gagarin sq., Rostov-on-Don, 344000, Russia),
daedwardrambler.ru@mail.ru

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HAZARD ANALYSIS AND ASSESSMENT OF PROFESSIONAL RISK IN THE MANUFACTURE OF CONSTRUCTION MATERIALS

Staseva E. V., Gorbatkova A. V., Velchenko A. A.
Don State Technical University, Rostov-on-Don, Russian Federation

elena_staseva@mail.ru
a.v.gorbatkova@mail.ru
gramotejka@mail.ru

The article considers the question of assessment of professional risk of workers. The analysis of conditions and safety of work in production of construction materials is carried out. The method of assessment of professional risk on the basis of integrated indicators of conditions and safety of work is offered. Interpretation of characteristics of working conditions on indicators of qualitative and quantitative standard of professional risk is given. Calculation of professional risk for the former of reinforced concrete structures is presented.

Keywords: production factors, harmful and dangerous working conditions, professional risk, risk assessment.

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АНАЛИЗ ОПАСНОСТЕЙ И ОЦЕНКА ПРОФЕССИОНАЛЬНОГО РИСКА ПРИ ПРОИЗВОДСТВЕ СТРОИТЕЛЬНЫХ МАТЕРИАЛОВ

Стасева Е. В. , Горбаткова А. В., Вельченко А. А.
Донской государственный технический университет, Ростов-на-Дону, Российская Федерация
elena_staseva@mail.ru
a.v.gorbatkova@mail.ru
gramotejka@mail.ru

Рассмотрен вопрос оценки профессионального риска работников. Проведен анализ состояния условий и безопасности труда при производстве строительных материалов. Предложен метод оценки профессионального риска на основе интегральных показателей состояния условий и безопасности труда. Дана интерпретация характеристик условий труда по показателями качественной и количественной оценки профессионального риска. Представлен расчет профессионального риска для формовщика железобетонных изделий.

Ключевые слова: производственные факторы, вредные и опасные условия труда, профессиональный риск, оценка риска.

Introduction. The economic development of our country at the present stage is accompanied by an increase in the need of building materials. These industries are part of the structure of the manufacturing industry — a branch of industry in which as raw materials we use products of different purposes and the results are both means of production and consumer goods. The number of people employed in this production is increasing every year. According to the statistics for 2017, about 12% of all workers were employed in the manufacturing industry of Russia. Production of construction materials is characterized by complex and traumatic working conditions. This is confirmed by the published data of Rostrud. For example, in 2017 the number of workers in the production amounted to 25,400 people, the manufacturing industry accounted for about 6,000 people, which accounted for 23% of the total number of injured people [1-3].

Problem statement. The paper proposes a method for occupational risk assessment based on integrated indicators of conditions and safety.

Theoretical part. In order to increase the level of safety in production, it is necessary to analyze all production factors and determine the level of occupational risk of workers based on the data obtained [4]. Production of construction materials includes manufacture of materials, parts and structures for all types of construction (reinforced concrete blocks, slabs, trays, non-pressure pipes, foundation blocks, staircases, piles, platforms and steps, lintel blocks). Technological processes of such industries are ac-

companied by the presence of both harmful and dangerous factors; therefore, there is the risk of injury and the development of occupational diseases. Occupational risk assessment is a process that is carried out stage-by-stage, taking into account the production factors that arise during operation [1, 5]. All production factors by the nature of the impact can be conditionally represented in the form of two main indicators:

- "HARM" — an indicator that characterizes the influence of labor conditions;
- "DANGER" — an indicator that characterizes the state of injury risk of production.

The influence of all production factors on workers during their working life occurs in their combination (complex). Therefore, for the assessment of occupational risks it is necessary to take into account the risk levels for each of the indicators of working conditions and safety [6]. Assessment of occupational risk based on integrated indicators "DANGER" and "HARM" is determined by the formula (Fig.1).

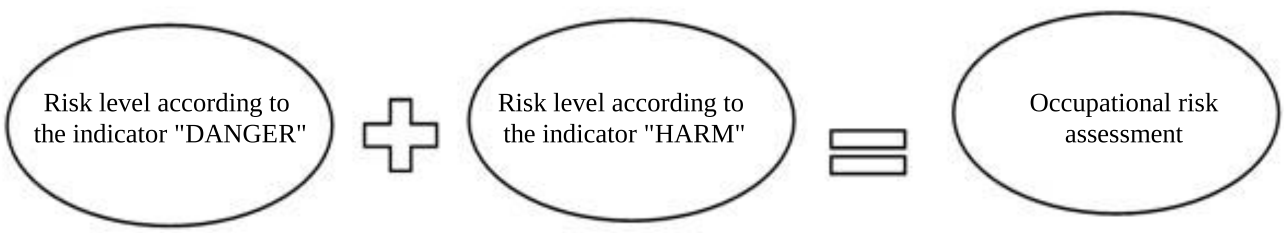

Fig. 1. Determination of occupational risk based on risk levels in terms of "DANGER" and "HARM"

The indicator "HARM" reflects the level of risk of influence of working conditions. It characterizes the possibility of development of chronic or acute diseases. To determine the level of risk in terms of "HARM", it is necessary to use the map of special assessment of working conditions of the workplace and to determine the level of risk on this indicator according to table 1 [7, 8].

Table 1

Risk level value according to the indicator "HARM"

Final class of working conditions	1	2	3.1	3.2	3.3	3.4	4
Risk level	1	2	3	4	5	6	7
Risk	Low	Acceptable	Minor	Significant	High	Very high	Catastrophic

The indicator of "DANGER" reflects the level of injury risk at the working place, characterizing the possibility of injury of workers from the influence of various hazards, leading to negligible injuries and to the fatal injuries [7, 8]. To assess the level of risk for the indicator "DANGER" they use data from the accidents statistical reports of the enterprise. The level of risk in terms of "DANGER" will be equal to the coefficient of injury frequency $K_{ч.т.}$, which is determined by the formula:

$$K_{ч.т.} = N\frac{1000}{P}, \qquad (1)$$

where N — the number of recorded occupational accidents with loss of labour capacity for one or more days during the reporting period; P — the average number of employees for the reporting period.

After determining the coefficient of injury frequency according to table 2, we determine the level of risk for this indicator.

Table 2

Risk level value according to the indicator "DANGER"

$K_{ч.т.}$	Risk level	Risk
≤1	1	Low
1–4	2	Acceptable
5–9	3	Minor
10–13	4	Significant
14–16	5	High
1–720	6	Very high
≥20	7	Catastrophic

Assessment of the occupational risk level based on integral indicators "DANGER", "HARM" and the formula from fig. 1 is according to table 3.

Table 3

Assessment of the value of occupational risk level based on integral indicators

Occupational risk		Risk level according to the indicator "HARM"						
		1	2	3	4	5	6	7
Risk level according to the indicator "DANGER"	1	2	3	4	5	6	7	8
	2	3	4	5	6	7	8	9
	3	4	5	6	7	8	9	10
	4	5	6	7	8	9	10	11
	5	6	7	8	9	10	11	12
	6	7	8	9	10	11	12	13
	7	8	9	10	11	12	13	14

The interpretation of the characteristics of working conditions by indicators of qualitative and quantitative occupational risk assessment is presented in table 4.

Table 4

Interpretation of characteristics of working conditions by indicators of qualitative and quantitative occupational risk assessment

Quantitative assessment of occupational risk level	Qualitative indicator of occupational risk level	Working conditions characteristics of the occupational risk level
from 2 to 4	Minimal	Absence of harmful and dangerous factors in the workplace, injury is unlikely.
fromт 5 to 7	Low	No exceedance of the hygienic standards of MPC (maximum permissible level) of harmful factors in the workplace; hazards are securely locked, microtraumas are possible.

Quantitative assessment of occupational risk level	Qualitative indicator of occupational risk level	Working conditions characteristics of the occupational risk level
from 8 to 11	Moderate	Harmful factors at the working place exceed acceptable levels of MPC (maximum permissible level); there are dangerous factors with the possible occurrence of a slight accident.
from 12 to 13	High	Harmful factors significantly exceed the MPC (MPL); there is a high probability of an accident with a severe outcome.
14	Ultrahigh	Harmful factors significantly exceed hygienic standards so that they can lead to acute poisoning; there is a high probability of a group accident or death.

Example. Let us carry out hazard analysis and occupational risk assessment at the workplace of a concrete products moulder of a construction materials plant. In accordance with the data of special assessment of working conditions card of the concrete products moulder the final class of working conditions — 3.2. According to table 1, we determine the value of the risk level in terms of "HARM". Risk level — 4 (significant risk). At the workplace, there are high levels of noise, vibration and harmful substances [9].

The initial material for the calculation of the indicator "DANGER" is the data of the report of the enterprise on accidents. The risk level according to the indicator "DANGER" depends on the injury frequency coefficient, which is determined by formula 1:

$$K_{ч.т.} = 2\frac{1000}{149} = 13.$$

According to table 2, we determine the value of the risk level by the indicator "DANGER" — 4 (significant danger). In table 3, we determine the value of occupational risk level for concrete products moulder — 8 (moderate). According to table 4, the level of occupational risk at the workplace of the concrete products moulder according to the integrated indicators "DANGER" and "HARM" indicates the presence of harmful factors, the values of which exceed the permissible levels, as well as there are dangerous factors that contribute to the occurrence of a light accident. Mutual influence of indicators in their joint action can strengthen the influence of each of them. It is necessary to develop measures to reduce the impact of harmful factors and possible injury [7].

Conclusion. The proposed method of occupational risk assessment based on integrated indicators allows us to characterize working conditions at the workplace, taking into account the joint action and interaction of industrial factors in terms of hazard and danger. The results of risk calculations for each workplace are proposed to be used in the development of preventive measures to improve the conditions and safety of the employees of enterprises for the production of construction materials, as well as in other industries.

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Autors:

Staseva Elena Vladimirovna,
associate professor of "Life Safety and Environmental Protection» department, Don State Technical University, (1, Gagarin sq., Rostov-on-Don, 344000, Russia), Candidate of Technical Sciences,
elena_staseva@mail.ru

Gorbatkova Alina Vladimirovna,
master student, Don State Technical University, (1, Gagarin sq., Rostov-on-Don, 344000, Russia),
a.v.gorbatkova@mail.ru

Velchenko Anastasiya Anatolevna,
master student, Don State Technical University, (1, Gagarin sq., Rostov-on-Don, 344000, Russia),
gramotejka@mail.ru

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FORECASTING FOREST FIRE BURNING AREA USING MACHINE TRAINING

Filippenko V. A., Zotov A. V.
Don State Technical University, Rostov-on-Don, Russian Federation

philippenko@inbox.ru,
azotzot@gmail.com

The objective of this article is to create and train an artificial neural network based on a data set containing various climatic parameters and future fire area as an output parameter that the authors intend to predict. Such a "set" of data is usually available for research and study. Before training the neural network model, the data set is divided into two samples: a sample for training, which is about 90% of the set; and a sample for testing the trained model. In setting the task, the authors select and analyze the known data on the fires that occurred in Montesinho Park, compare the models trained on these data with and without normalization. As a result, two examples are given of a qualitative demonstration of graphs of absolute error changes of fire areas, which are projected using the created and trained model.

Keywords: burning area, machine training, model, neural networks, *Keras*, forecasting, forest fire.

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ПРОГНОЗИРОВАНИЕ ПЛОЩАДИ ГОРЕНИЯ ЛЕСНОГО ПОЖАРА С ПОМОЩЬЮ МАШИННОГО ОБУЧЕНИЯ

Филиппенко В. А. , Зотов А. В.
Донской государственный технический университет, Ростов-на-Дону, Российская Федерация
philippenko@inbox.ru,
azotzot@gmail.com

Целью настоящей работы является создание и обучение искусственной нейронной сети на основе набора данных, содержащих различные климатические параметры и будущую площадь пожара в качестве выходного прогнозируемого параметра. Такой набор данных является, как правило, доступным для исследования и изучения. Перед обучением модели нейронной сети набор данных разделяют на две выборки — выборка для обучения, которая составляет около 90 % от набора, и выборка для тестирования обученной модели. В постановке задачи авторы выбирают и анализируют известные данные о пожарах в парке Монтезиньо (*Montesinho*), сравнивают модели, обученные на этих данных с нормализацией и без нее. В качестве результата приведены два примера графиков изменения абсолютной ошибки площадей пожара, прогнозируемых с помощью созданной и обученной модели.

Ключевые слова: площадь горения, машинное обучение, модель, нейронные сети, *Keras*, прогнозирование, лесной пожар.

Introduction. A forest fire is a natural and uncontrolled spread of fire over forest areas. According to the Federal Forestry Agency in a week from June 3 to June 9, 2019 in 45 regions of Russia, forest fire forces and contractors extinguished 354 forest fires on the area of 5783.2 hectares, including 98 fires on the area of 1790.05 hectares, which were extinguished during the weekend of June 8-9. Due to smoke in fires, about 300 thousand people die every year. As a result of the combustion of biomass, an aerosol-gas mixture is formed, which represents an ecological and toxicological risk for humans.

Fire-fighting service personnel should be provided with the most effective fire-fighting equipment and equipment for natural phenomena elimination. However, often this is not enough to fight this dangerous phenomenon effectively. Strategic planning and resource allocation, such as the provision of a suffi-

cient number of fire-fighting aircrafts or ground crews, can significantly improve the chances of fire control. But you need to calculate the amount of resources that can take a lot of time.

One way to solve this problem can be the use of neural networks. In the present work, the authors used the data on fires in the Montesinho Park in Portugal to train and test the neural network. This set of data is available for research and work [1]. The authors use the *Keras* neural network library [2], written in the *Python* programming language [3, 4].

Data preparation. The Montesinho Park fire data were chosen as a training material for the neural network model due to the fact that the complex fire hazard indicator of V. G. Nesterov used in the Russian Federation contains fewer parameters, and this may be the cause of lower results in the training of the model. The set of parameters used by the authors, in addition to traditional ones, contains the following parameters: moisture content of forest litter and soil, flame characteristics, anthropogenic factor and thunderstorm activity. The following are additional parameters of the rating system of forest fire danger, which were used in the formation of this set [5]:

• probability of fire (*Fine Fuel Moisture Code, FFMC*);

• coal moisture rate (*Duff Moisture Code, DMC*);

• drought rate (*Drought Code, DC*);

• index of the initial spread system (*Initial Spread Index, ISI*).

All meteorological data for the calculation of the above mentioned components can be requested from the nearest meteorological service. Since this data set contains quite a lot of climatic parameters, with the help of the created and trained model it will be possible to predict the future area of a fire not only for the Montesinho Park, but also for any other similar territory.

Complete data in the set:

• *X* — X-axis spatial coordinate on the Montesinho Park map: from 1 to 9;

• *Y* — Y-axis spatial coordinate on the Montesinho Park map: from 2 to 9;

• "month" — month of the year: from January to December;

• "day" — day of the week: Monday to Sunday

• *FFMC* — the index of ease of ignition of the fuel from the *FWI* system over the interval 18.7–96.2;

• *DMC* — the index of coal moisture content rate from the *FWI* system over the interval 1.1 to 291.3;

• *DC* — the index of drought rate from the *FWI* system over the interval 7.9–860.6;

• *ISI* — the index of initial distribution from the *FWI* system over the interval from zero to 56.1;

• "Temperature" — temperature in the range of 2.2–33.3°C;

• relative humidity from 15.0 to 100 %;

• "Wind" — wind speed from 0.4 to 9.4 km/h;

• outside rain from 0.0 to 6.4 mm/m^2;

• "Area" — burned forest area from 0.00 to 1090.84 ha.

All the parameters in the set are changed in different ranges. In order to improve the prediction accuracy of the model, it is necessary to normalize the data. One way to normalize the data is to subtract the mean from each parameter and divide it by the standard deviation. After these actions, the average value will be zero and the variance will be one. In this case, the data in each column will vary from -1 to +1, but with this method of normalization, some columns may have negative values, which may not be the case

for some parameters. You can use the *MinMaxScaler().fit_transform()* procedure to resolve this problem [6], which converts all data to the range 0 ... +1. This model is trained by "supervised training". In this case, the data is divided into two parts — the data for training and the correct answers for this data. The data for training are needed to train the model, and the answers are needed to recalculate the weights on the edges of the neural network graph when the predicted value and the actual value do not match. Before training, we will randomly divide this data into a training sample and a test sample. The training sample is part of the dataset used to train the model. It will be about 90 % of the set. The test model is 10 % of the dataset and is used to test the effectiveness of the model. The test data will not participate in the training of the model, it is used only to verify the functionality. In the following, such modeling can be associated with the classical construction of models and the calculation of technosphere safety indicators [7, 8].

Creation of a model. In the testing of different models for the dataset under consideration, the model with 6 layers was the best: the input layer with 24 neurons, 4 hidden layers containing 48, 96, 48, 24 layers, and the output neuron.

The following activation functions were used:

• linear — on the first, second and fifth layers;

• sigmoid — on the second and third layers, it allows you to amplify weak signals without being saturated with strong ones;

• *selu* — on the output neuron, increases the convergence rate of the neural network.

When compiling the model, "*adadelta*" was used as a gradient descent type optimizer. *Adadelta* updates smaller weights that are too frequently updated, but, in contrast to *Adagrad*, instead of the full amount of updates will use the average value with respect to the history of the square of the gradient.

As an error function, which will be used by the optimizer in the error back propagation algorithm, we choose the standard error, as a metric- "*mae*", the average absolute error.

Training. In the 500-stage of training, the average absolute error is 4.6, so the model in the predictions will be wrong in general by 4.6 hectares, which the authors consider satisfactory. Fig. 1 shows the curve of the error change.

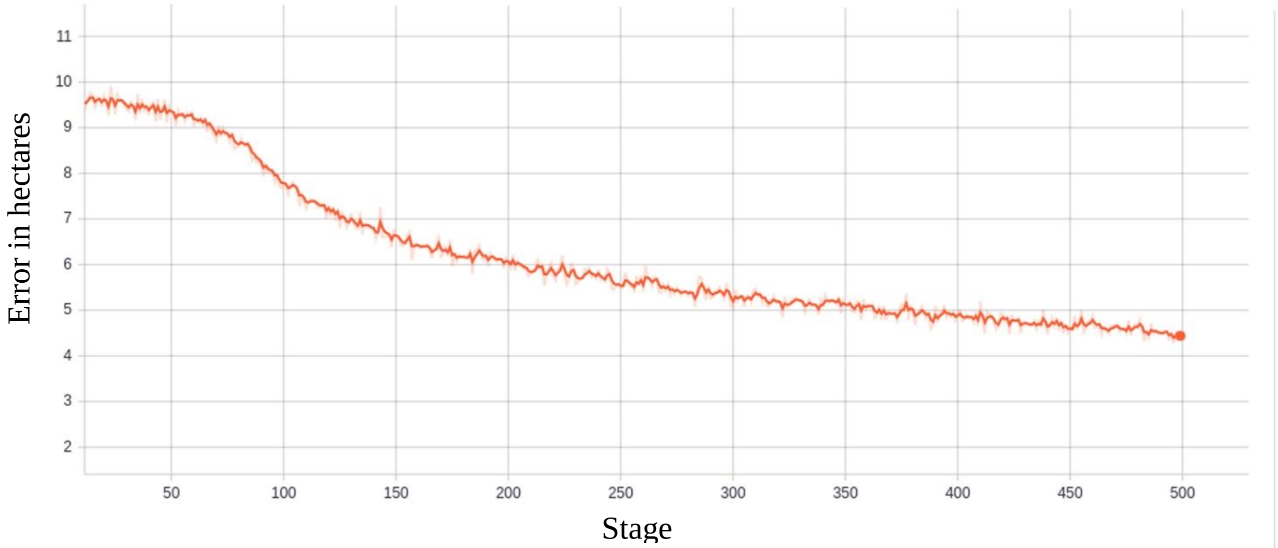

Fig. 1. Curve of an absolute error change at training on data with normalization

Fig. 2 shows a graph of an absolute error change with unnormalized data, which proves that the normalized data is better than the initial data.

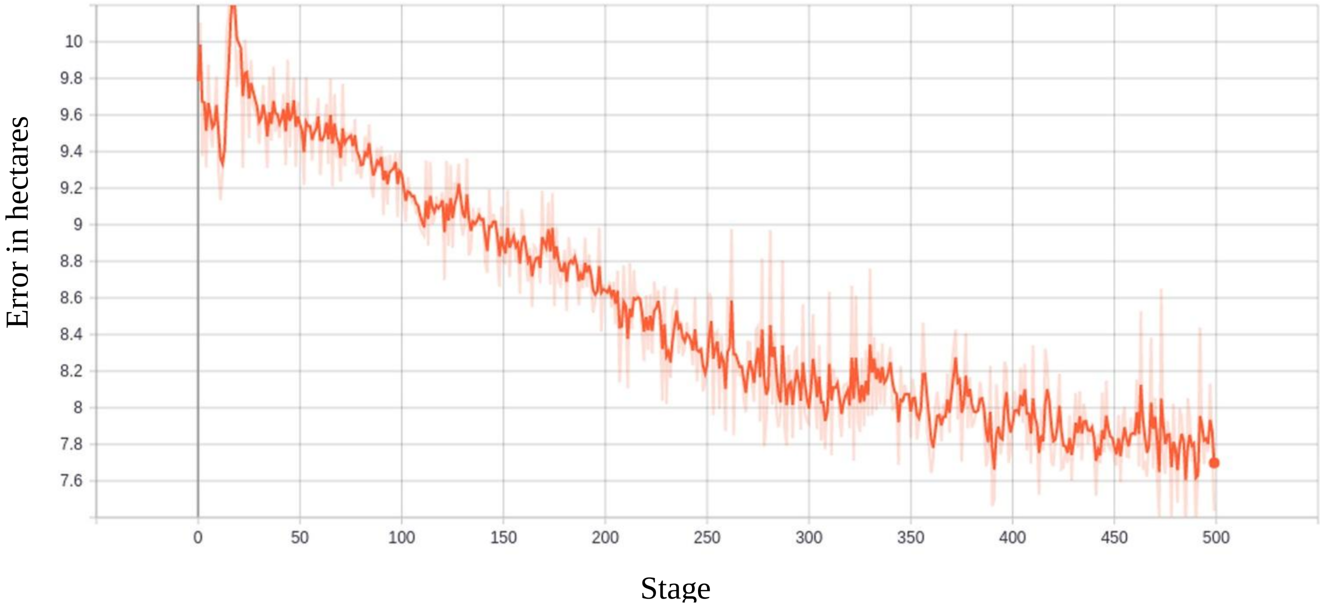

Fig. 2. Curve of an absolute error change at training on data without normalization

Forecasting. Fig. 3 provides a graph illustrating the results of the neural network operation. On the graph, the orange line is the actual burning area; the blue line is the predicted area. As it can be seen in the figure, the dynamics of the curves for each record is almost identical, which shows the good performance of the trained model in forecasting.

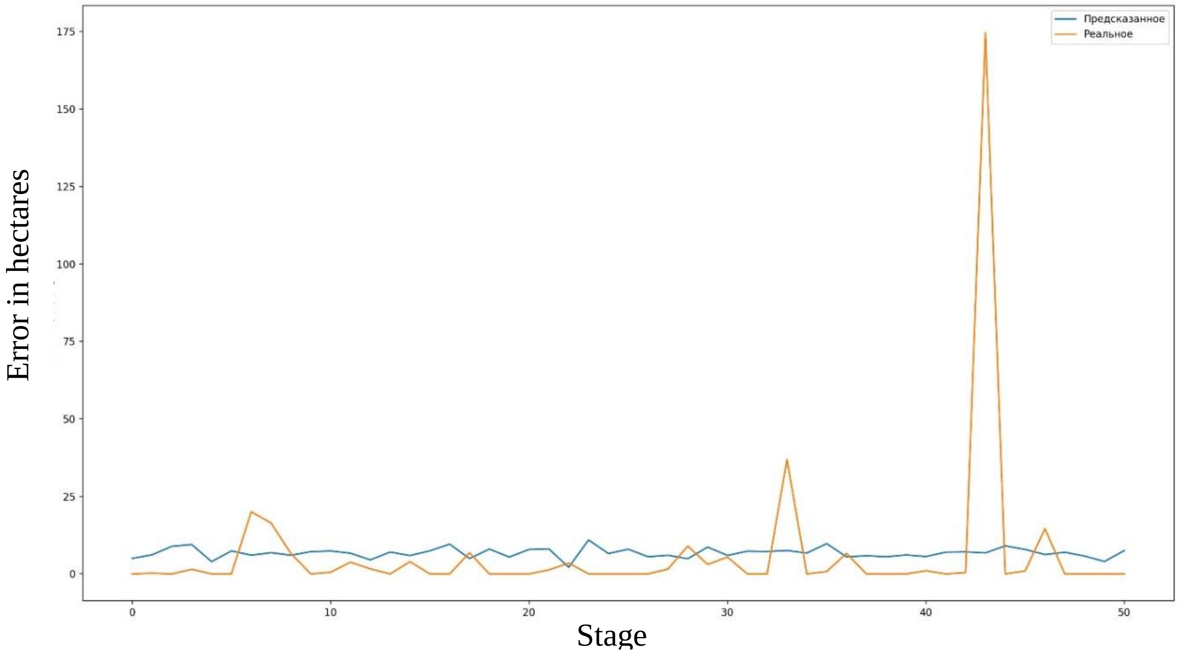

Fig. 3. Forecasting using the trained model with the normalized data

Fig. 4 demonstrates the forecasting graph of another model, which was trained with the help of unnormalized data. Obviously, the first model is more effective.

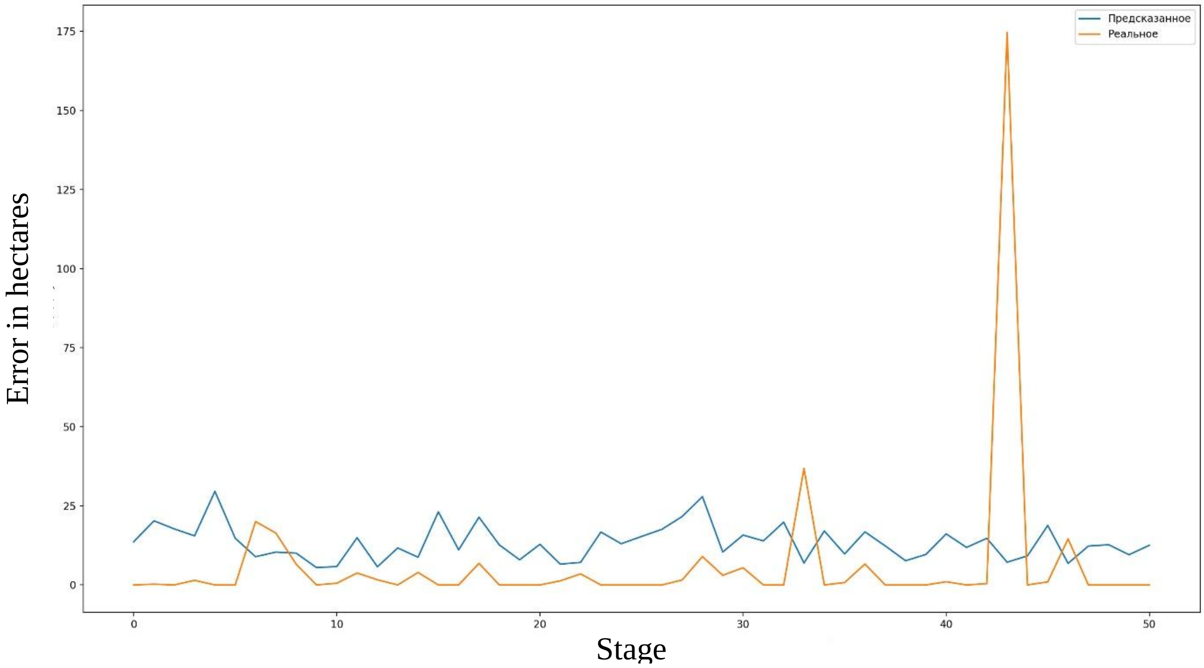

Fig. 4. Forecasting using the trained model with unnormalized data

Conclusion. In this paper, a model of an artificial neural network was created and trained on a set of data containing different climatic parameters and the future fire area in hectares. This area is the output parameter that the authors are going to forecast. As a rule, this dataset is available for research and study. Before training the neural network model, the dataset was divided into two samples: a sample for training, which is about 90 % of the set, and a sample for testing the trained model. In the formulation of the problem, the authors choose and analyze the known data on the fires that occurred in the Montesinho Park, compare the models trained on these data with and without normalization. As a result, two examples of demonstration of the absolute error graphs of the fire areas predicted by the created and trained model are given.

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Autors:

Filippenko Viktor Aleksandrovich,
student, Don State Technical University, (1, Gagarin sq., Rostov-on-Don, 344000, Russia),
philippenko@inbox.ru

Zotov Aleksey Vyacheslavovich,
student, Don State Technical University, (1, Gagarin sq., Rostov-on-Don, 344000, Russia),
azotzot@gmail.com

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ENVIRONMENTAL PROBLEMS OF THE CASPIAN SEA. LEGAL ASPECT

Anapolskiy S.Yu.
Don State Technical University, Rostov-on-Don, Russian Federation

anapolsky2013@yandex.ru

The paper deals with the legal aspect of the problem of waters pollution of the Caspian Sea and further consequences. Modern ecological problems of the Caspian Sea are specified. Various normative legal acts are studied in detail; violations of both the norms of Russian law and international law are investigated.

Keywords: environmental law, international environmental law, water legislation, environmental violations during the extraction of natural resources.

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ЭКОЛОГИЧЕСКИЕ ПРОБЛЕМЫ КАСПИЙСКОГО МОРЯ. ПРАВОВОЙ АСПЕКТ

Анапольский С. Ю.
Донской государственный технический университет, Ростов-на-Дону, Российская Федерация
anapolsky2013@yandex.ru

Рассматривается правовой аспект загрязнения вод Каспийского моря и дальнейшие последствия загрязнений. Обозначены современные экологические проблемы Каспийского моря. Подробно изучены различные нормативно-правовые акты, исследованы нарушения норм как российского, так и международного права.

Ключевые слова: экологическое право, международное экологическое право, водное законодательство, экологические нарушения во время добычи природных ресурсов.

Introduction. People started researching hydrology in the first half of the 19th century. In the first decades of the Soviet power, they started the exploration of the seabed and natural resources in the Caspian Sea. The main resource was oil, which eventually became one of the main causes of environmental problems of the Caspian Sea. After the collapse of the USSR, the Caspian Sea borders were divided between 5 countries. These are the borders of the Russian Federation, the Republic of Azerbaijan, the Islamic State of Iran, Turkmenistan and the Republic of Kazakhstan. Before the collapse of the USSR, these were the borders of two countries — the USSR and Iran. After 12 years (04.11.2003) in Tehran, all the Caspian countries signed the "Framework Convention on the Protection of the Marine Environment of the Caspian Sea" [1]. A little earlier (10.06.2003) in the media there was information that in the coastal zone of the Kazakhstan sector of the Caspian Sea there was oil spilled from 4 wells, suspended in the 70-ies of XX century. Plumes from leaks up to 20 meters large stretched along the shore at a distance of 1 kilometer. Perhaps this case contributed to the signing of the Framework Convention by the Caspian countries.

Russian and international legal acts regulating the protection of the Water Fund of the Caspian Sea. The coastal regions with natural resources, has always attracted the world's attention. The increasing economic use of these zones necessitates a comprehensive study of the potential of natural systems for their sustainable development, as well as the development of the adjacent territories [2].

The Russian Federation and the Republic of Kazakhstan signed the international agreement "On the division of the Northern part of the Caspian Sea bottom for the purposes of sovereign mineral resources management" on 06.07.1998 [3]. The first article of the agreement states: "the bottom of the Northern part of the Caspian Sea and its subsoil, while maintaining the common use of the water surface, including freedom of navigation, agreed fishing standards and environmental protection, shall be distinguished between the Parties along the median line, modified on the basis of the principle of justice and understandings between the parties".

At the summit of the heads of the Caspian States in 2014, all its participants came to a decision that most of the Caspian Sea area remains a territory of common use of the Caspian countries in order to avoid subsequent conflicts. The same ideology is characteristic of the above-mentioned Framework Convention on the Protection of the Marine Environment of the Caspian Sea.

Since the main objective of the Convention is to protect the marine environment of the Caspian Sea from pollution, including protection, conservation, restoration, sustainable and rational use of its biological resources, the idea of the Convention seems to be correct. This Convention regulates the relations in the field of protection of objects of flora and fauna, listed in the Red Book of all Caspian States, as well as the protection of health and life of people living in the coastal areas of the sea and on the banks of rivers that flow into the Caspian Sea. There are 130 such rivers and the largest of them is the Volga.

The sphere of protection of nature and human habitat is regulated by article 42 of the Constitution of the Russian Federation [4], which states that everyone has the right to a favorable environment, reliable information about its status and to compensation for damage caused to his health or property by an environmental offense. Federal law of 24.04.1995 no. 52-FZ "On the animal world" [5], Federal law of 10.01.2002 no. 7-FZ "On environmental protection" [6] and the Water code of the Russian Federation of 03.06.2006 no. 74-FZ [7] are the Federal laws of the Russian Federation regulating the Caspian Sea protection.

The objects of fauna living on the territory of the Caspian Sea and listed in the Red book of Russia [8] include fish:

• Sturgeon — sturgeon and thorn sturgeon;
• Clupeidae — Volga shad;
• Salmonidae — white salmon, Caspian salmon, Salmo ezenami;
• Cyprinids — Rutilus frisii kutum;
• Cobitidae — Caucasian spiny loach;
• Percidae — Volga Perch;
• Petromyzontidae — Petromyzon wagneri.

This category also includes the Anatidae birds — the marbled duck, the great white pelican, Caucasian common newt. And this is not a complete list of those animals that live on the coast of the Caspian Sea and are on the verge of extinction [9].

Environmental violations in natural resources extraction and the consequences of these violations. The first oil production activities in the Caspian Sea began in 1820. Since then, oil production at the sea has progressed for the better for the state in terms of economy, but not for the environment. Many scientific expeditions are looking for new oil deposits in the world's oceans, without thinking about the consequences to which these developments can lead. Oil production or transportation in the Caspian Sea often led to disasters. According to the author, there have been several cases of oil leaks into the water without any information about these leaks. Along with this, we know about a major leak that occurred on 25.03.2009. On this day, a video was posted on social networks, where eyewitnesses shot the moment of ignition and splashing of oil into the coastal waters of the Caspian Sea. Soon all news, including the information portal "Nastoyashchee vremya", reported about this event. At the same time, a number of Kazakh officials claimed that the leak could not be attributed to a technogenic disaster, as nobody was injured, and the environment suffered only minor damage. However, if we analyze the results of studies of scientists around the world on this topic, it turns out that 1 drop of oil makes 25 liters of water undrinkable, and judging by the footage from the published video, in this case there was a leak of quite a large volume. Such leaks can lead to a global catastrophe not only for the animal world in the waters of the Caspian Sea, but also for people. When oil is spilled into the water in large quantities, the water is cov-

ered with a thin oil slick, which can lead to the death of many inhabitants of the Caspian waters, including fish listed in the Red book.

Here it is appropriate to draw analogies of technogenic consequences of the considered case and catastrophes of another kind, as a result of which a large number of people, animals and plants have been lost. This is the 1986 Chernobyl disaster and the use of nuclear weapons by Americans during World War II in Hiroshima and Nagasaki. Almost half of the Earth's ozone layer has been destroyed by humankind because of the large amount of carbon dioxide released into the atmosphere. As a result, the average temperature on Earth begins rising, which contributes to the rapid melting of the ice of Antarctica, Greenland and other glaciers around the world. If this continues, tsunamis with a height of 60-100 meters can be triggered. It is obvious that now the humankind got used to do anything with nature, and to feel unpunished [10]. It does not care for itself, for its descendants, and dooms them to certain death. Is not it the time to think about it and start taking comprehensive measures, otherwise the humanity will eventually pay for such an attitude to nature?

Conclusion

The unfavorable ecological situation takes place not only in the waters of the Caspian Sea, but also on the whole territory of Russia. This situation is typical for many areas of the planet due to the constant human intervention in nature. It is hoped that the humanity will understand that any resource of the planet is not infinite, and it is impossible to treat nature and its resources so carelessly. Urgent measures should be taken to conserve those resources, whether in the Pacific Ocean or in the small forest near the village or the state.

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Autors:

Anapolskiy Sergey Yurevich,
student, Don State Technical University, (1, Gagarin sq., Rostov-on-Don, 344000, Russia),
anapolsky2013@yandex.ru

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ECOLOGICAL CONDITION MONITORING OF THE RIVER TEMERNIK WITHIN THE BOUNDARIES OF THE SEVERNY RESEDENTIAL AREA OF ROSTOV-ON-DON

Makagon Yu.V., Abrosimova E.B.
Don State Technical University, Rostov-on-Don, Russian Federation

makagon.j@yandex.ru
abrosimovaekaterina@yandex.ru

This article studies ecological problems of the Temernik, located within the boundaries of the residential area "Severny" of Rostov-on-Don. Nowadays the river is under the threat of disappearance. The authors analyze water hydrochemical indicators using short-term tests and compare it with normative requirements for water-quality of fishing water bodies. Water samples were taken in different places of the river with the total length of 2.8 km.

Keywords: the Temernik, ecological situation, hydrochemical indicators, fishing water body, main pollutants.

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МОНИТОРИНГ ЭКОЛОГИЧЕСКОГО СОСТОЯНИЯ р. ТЕМЕРНИК В ГРАНИЦАХ МИКРОРАЙОНА «СЕВЕРНЫЙ» РОСТОВА-НА-ДОНУ

Макагон Ю. В., Абросимова Е. Б.
Донской государственный технический университет, Ростов-на-Дону, Российская Федерация
makagon.j@yandex.ru
abrosimovaekaterina@yandex.ru

Рассмотрены экологические проблемы реки Темерник, расположенной в границах микрорайона «Северный», г. Ростова-на-Дону. В настоящее время река находится на грани исчезновения. Проанализированы гидрохимические показатели с использованием экспресс-тестов. Проведено сравнение с нормативными требованиями к качеству воды для рыбоводных водоемов. Пробы воды были отобраны в разных точках реки общей протяженностью 2,8 км.

Ключевые слова: река Темерник, экологическое состояние, гидрохимические показатели, рыбоводный водоем, основные загрязнители.

Introduction. The length of the river Temernik within the boundaries of Rostov-on-Don is about 18 km. It flows in different parts of the city and for many decades the ecological state of the river has been deteriorating every year. The worst part of it is in the place where it flows into the river Don, where it turned into a gutter bounded by concrete. At the same time in the city, there are houses, urban recreation areas, organized beaches on its banks. The river flows through the zoo, Botanical garden, i.e. it is an important part of the urban ecosystem. In recent decades, several city programs for cleaning of the river Temernik were developed, which did not lead to the improvement of the ecological situation. Currently, a new project is being implemented, the aim of which is not just cleaning, but full rehabilitation of the river by 2025. The task involves not just cleaning the river from debris, but also the complete restoration of the aquatic ecosystem.

Main part. Hydrochemical characteristics of the reservoir on the parameters that determine the living conditions of hydrobionts is one of the objective characteristics of its ecological state. Therefore, the purpose of this work was to study the most important for hydrobionts water indicators in the selected section of the river from the source in Surp Khach area to the dam located in the BSMP-2 area. The

length of the river suggests that in different parts of the city its environmental condition may differ. The study area is characterized by the presence of a large underground source and a wide water plane supported by two dams located at a short distance from each other. The shores of the reservoir are densely populated, there is an outdoor water park, organized recreation areas and the city beach.

The length of the river, where water samples were taken, is about 2.8 km. Four stations were selected for sampling (Fig. 1).

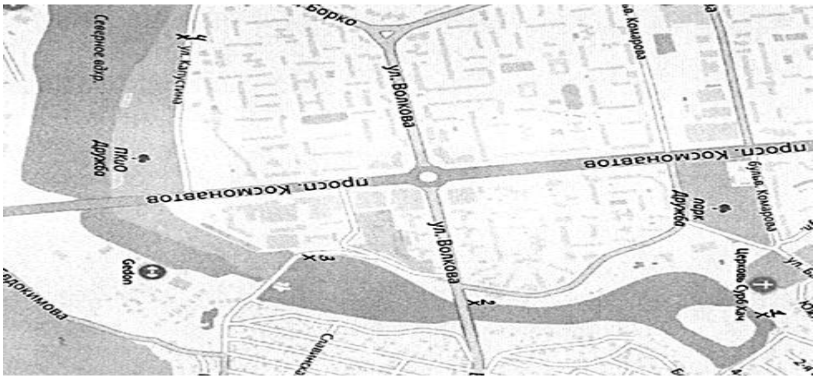

Fig. 1. Sampling points on the Temernik: 1 — area of Surp-Khach spring;
2 — under the bridge on Volkova street; 3 — the area of the dam;
4 — urban area of the beach in front of BSMP before the 2nd dam
(Yandex. Maps)

The most significant for the life of hydrobionts indicators of water were determined.

The concentration of oxygen dissolved in water is one of the main indicators affecting the life of hydrobionts. It is necessary for breathing for all aquatic organisms. Its optimal content is associated with species characteristics. For most fish, sufficient oxygen concentration is at the level of 5-6 mg/l. An important function of oxygen in the reservoir is also determined by its role in the process of mineralization of organic substances.

Hydrogen index (pH) (concentration of free hydrogen ions) in the reservoir is determined mainly by the ratio of free carbon dioxide and bicarbonate. Neutral pH is most favorable for fish. Deviation from these concentrations leads to a decrease in the respiratory intensity of fish. However, resistance to pH depends on the fish species. Thus, pike is tolerant to fluctuations in pH between 4.8 and 8.0; trout — 4.5–9.5; carp — 4.3 to 10.8 units [1].

All nitrogen compounds have a great influence on the production of organic matter in water bodies. Nitrate and ammonia nitrogen are most important in terms of bioproduction. However, the high content of nitrogen compounds in the reservoir can cause poisoning of hydrobionts. The most toxic compounds are ammonium and nitrites.

Phosphorus also has a significant impact on the development of organic life of water bodies. Intensive development of algae occurs at the initial content of mineral phosphorus from 0.08 to 0.32 mg/l. An increase in the phosphate content to several milligrams per liter points, as a rule, to the pollution of the reservoir.

For freshwater fishponds, these indicators should correspond to the values presented in table 1.

Table 1

Requirements to water quality in fishponds (Kozlov V. I., 1998)

Indicators	Optimum values	Permissible vLUEA
Oxygen, mg/l	Not less than 4.0	2.5
Violent reaction (pH)	7.0	6.5–8.0
Ammonium nitrogen (NH_3/NH_4), mg/l	0.5–1.0	1.5
Free ammonia (NH_3), mg/l	0.01	0.07
Nitrites (NO_2), mg/l	0.5–1.5	15.0
Nitrates (NO_3), mg/l	1.0–2.0	30.0
Phosphates (PO_4), mg/l	0.2	2.0

Sampling for the study was carried out on October 20, 2017 at the air temperature of $+6^0$ C and water temperature of $+11^0$ C. These conditions correspond to the end of active vegetation processes in the reservoir and can be further used to compare seasonal changes in water parameters in this area of the Temernik.

Hydrochemical study of samples was carried out using rapid tests of the company "Sera" according to the established methods.

Water samples were taken into the glass bottles with a stopper without fixation. The parameters were determined immediately. The data obtained are presented in table 2.

The data obtained show that the permissible concentrations of nitrate and phosphate compounds are 7.5 and 2 times higher, respectively.

Table 2

Hydrochemical parameters of water of the river Temernik on the study area

NN Station	pH	NO_2, mg/l	NO_3, mg/l	NH_3/NH_4, mg/l	NH_3, mg/l	PO_4, mg/l	O_2, mg/l
1	7.5	0.1	20	1.0	0.006	1.0	0.4
2	8.5	4.0	40	5.0	0.770	1.0	4.0
3	8.0	4.0	40	5.0	0.727	1.0	5.0
4	8.5	4.0	40	5.0	0.770	1.0	3.5

The greatest pollution of the reservoir is with ammonia compounds, and concentration in water of the most toxic form — free ammonia exceeds permissible indicators in fishponds by 11 times.

At the same time, such important hydrochemical parameters as violent reaction and the concentration of dissolved oxygen in water are within the normal limits, except for the oxygen content in the water samples at station 1.

Thus, we can say that in this area of the river Temernik there is a significant pollution with nitrogen and phosphorus compounds. In the area of the outlet of the underground source (station 1)

hydrochemical parameters meet the requirements of the water quality for fishponds (except oxygen). Industrial or private sewage are not noted on this site, but there are several pipes with storm drains. In addition, there is contamination of the reservoir and its shores by household garbage.

Conclusion. Probably, the significant concentrations of nitrogen and phosphorus compounds in the river are primarily associated with the strong overgrowth of the reservoir and the destruction processes of dead plants combined with its weak flowage in the study area.

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Autors:

Makagon Yuliya Vladimirovna,
student, Don State Technical University, (1, Gagarin sq., Rostov-on-Don, 344000, Russia),
makagon.j@yandex.ru

Abrosimova Ekaterina Borisovna,
associate professor, Don State Technical University, (1, Gagarin sq., Rostov-on-Don, 344000, Russia), candidate of biological sciences,
abrosimovaekaterina@yandex.ru